

# Analysis on Integrals of Lean Module Technologies

## The Cases of Visual Management, Poka-Yoke and Karakuri Technologies

Koichi Murata\*, Keizo Wakabayashi, Akihiro Watanabe, Hiroshi Katayama

\*Graduate School of Creative Science & Engineering, Waseda University,  
3-4-1 Ohkubo, Shinjuku Ward, Tokyo, 169-0072, Japan.

\*k-murata@kata.mgmt.waseda.ac.jp

### Abstract

In the context of accelerating globalization and a complex business environment, the development of hybrid technologies using existing methodologies for synergistic outcomes has been recognized as a novel management problem. Therefore, this paper addresses the integration of methodologies originating in the lean management scheme and analyzes the impacts on business performance. The results suggest that based on several measures such as elimination of useless operations, worker training, energy conservation, and so on, the degree of leanness is significantly elevated by the utilization of combined elementary technologies.

### Keywords

*Lean Management; Supply Chain Management; Manufacturing Site; Module Technology; Integral Technologies; Synergistic Outcome; Visual Management (Vm); Poka-Yoke (Fool-Proof); Karakuri*

### Introduction

Lean management is regarded as an effective business strategy for constructing effective and reliable supply chains operating throughout the world. Based on the constitutional concept of this management style, that is, a contradiction-driven approach, a number of methodologies and case applications have been developed in the manufacturing industry, a major player in supply chains. However, in the context of accelerating globalization and a complex business environment, many novel management problems have been recognized, such as managing both business functions and industries; the reinforcement of lean management transferability among manufacturing sites including offshore plants; the necessity of developing hybrid technologies using existing methodologies for synergistic outcomes; and so on.

Therefore, this paper discusses the integration of methodologies originating in the lean management

scheme and analyzes the impacts on business performance. Three module technologies categorized as elementary lean technology are the focus of the examination: visual management (VM), *poka-yoke* (fool-proofing), and *karakuri* (sophisticated mechatronic contrivance for efficient operations).

The outcome of this paper that is the extracted key phases and terms of the integrals, will contribute to the improvement on the mobility of the lean technologies. To be more concrete, the related knowledge database will be made by an electronic information system. Owing to it, a lean management scheme will be extended not only to manufacturing site but also to various sites in a total supply chain such as a design site, a wholesale site and a sales site etc.

This paper consists of eight sections. In the next section, a matrix is proposed to analyze the integrals of focused lean module technologies through a literature survey. After an explanation of the integrals is analyzed in the third section, three case studies of integral analysis are performed from the fourth section to the sixth section. A general recognition of the advantages of integral technologies based on the three case studies is presented in the seventh section, and conclusions are made in the final section.

### Lean Module Technology

This section discusses single lean module technology and integrals of lean module technologies.

First, this paper focuses on three single lean module technologies: VM technology, *poka-yoke* technology, and *karakuri* technology. Many cases of each technology developed in various factories have been introduced in exhibitions, papers, and books (Erlandson 1998, Murata and Katayama 2010, Murata and Katayama 2013, Nakajo and Kume 1991, Shigeo 1986, TPM Age Editorial 1999, JIPM 2009). This

indicates that they are useful for improving production system capability and various supply chain functions. Each technology is compact and not very complicated. Therefore, it is easy to parse a mechanism of integrals through focused technologies. After the literature survey, the features of each technology are extracted from the first sub-section to the fourth sub-section.

Second, integrals of plural module technologies are the focus as one type of integral to use for relevant research. Two of the three module technologies mentioned above are the focus. In order to clarify the technological features, a support matrix is proposed shown in FIG. 1. The first step is an extraction of two axes based on the results of the literature review in the previous section. Each axis comprises several instances of elemental technology for one lean module technology. The second step is the creation of a matrix utilized in the two established axes.

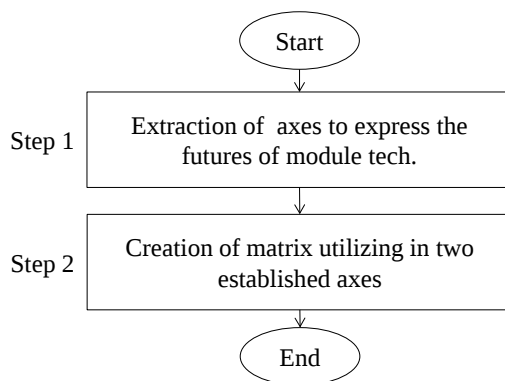


FIG. 1 DEVELOPMENT PROCEDURE OF PROPOSED MATRIX

### Visual Management Technology

The development of VM technology originally begun in the production sector. Its importance in manufacturing industries has been described in past research (Murata and Katayama 2010, Murata and Katayama 2013, Ohno 1988). In recent years, it has been used in other corporate sectors, including administration, engineering, and sales. The trend indicates that it contributes to lean management, which is a useful scheme for the entire supply chain.

VM technology uses the sense of sight to detect various types of information about objective systems. However, humans have other senses such as hearing, smell, taste, and touch, few examples using these senses can be found. Hence, case development using "five-sense technology," as one concept of advanced VM technology, is necessary to use more human capabilities to improve business performance.

### Poka-Yoke Technology

Shingo (1986) defined *poka-yoke* (fool-proof) technology as one lean technologies for supporting zero quality control. It is useful for improving the productivity of objective systems and creating employment opportunities for workers with disabilities by preventing various missteps and/or errors in the production process, including processing, assembly, set-up, inspection, and so forth. (Erlandson 1998, Nakajo and Kume 1991, Nikkan Kogyo Shimibun 1989, Shigeo 1986).

The technological element of *poka-yoke* technology, a trigger factor to prevent relevant mistakes, is classified into three types: product oriented, operation oriented, and machine oriented. The following list shows examples of the trigger factor of each orientation.

- Product oriented
  - Weight
  - Number
  - Location, etc.
- Operation oriented
  - Order
  - Timing, etc.
- Machine oriented
  - Life of a machine part
  - Number of lines in a computer program, etc.

### Karakuri Technology

The Japan Institute of Plant Maintenance (JIPM), leading promoter of total productive maintenance and management (TPM), held an exhibition on *karakuri* technology in Japan (JIPM 2009) with the purpose of not only exchanging ideas about the displayed technologies among domestic manufacturers but also introducing TPM activities to overseas manufacturers.

The purpose of *karakuri* technology is to automate an objective operation. One category of low-cost automation (LCA) is considered (Albertos 1989). *Karakuri* technology is used to make objective operations easier and to increase productivity. The technology uses a simple mechanism based mainly on the natural principles of the following (TPM Age Editorial 1999):

- Mechanics
  - Lever
  - Pulley
  - Gear wheel

- o Cam-link mechanism
- Hydromechanics
- Magnetism
- Electricity
- Sound
- Optics
- Physical properties

### Technologies' Features

TABLE 1 LEAN MODULE TECHNOLOGIES' FEATURES

| Lean module tech.      | Main purpose             | Elemental tech.                | Instances of elemental tech.                                                                                         |
|------------------------|--------------------------|--------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Five-sense tech.       | Detection of information | Five senses                    | Sight<br>Hearing<br>Smell<br>Taste<br>Touch                                                                          |
| <i>Poka-yoke</i> tech. | Prevention of mistakes   | Trigger factors                | Weight<br>Number<br>Location<br>Order<br>Timing<br>Life of machine part<br>Number of lines in computer program, etc. |
| <i>Karakuri</i> tech.  | Automation               | Natural engineering principles | Mechanics<br>Hydromechanics<br>Magnetism<br>Electricity<br>Sound<br>Optics<br>Physical properties                    |

TABLE 1 shows a list of features of the three lean module technologies based on the survey of each technology above. The list includes (1) the main purpose, (2) the elemental technology, and (3) instances of the elemental technology. In particular, the third item is used to create a matrix to dissect a case using plural module technologies.

### Matrix for Plural Module Technology Integrals

Support matrixes are illustrated from TABLE 2 to TABLE 4. Each of them is used to integrate two lean module technologies. The axes of the proposed matrices are based on elemental technology instances for each technology as shown in TABLE 1.

A matrix for integrals of five-sense technology and

*poka-yoke* technology is shown in TABLE 2. The components of the vertical axis are the five senses: sight, hearing, smell, taste, and touch. The components of the transverse axis are six trigger factors: weight, number, location, order, timing, life of a machine part, and number of lines in a computer program.

A matrix for integrals of five-sense technology and *karakuri* technology is shown in TABLE 3. The components of the vertical axis are the five senses: sight, hearing, smell, taste, and touch. The components of the transverse axis are seven natural principle factors: mechanics, hydromechanics, magnetism, electricity, sound, optics, and physical properties.

TABLE 2 MATRIX CLARIFYING THE TECHNOLOGICAL FEATURES OF THE INTEGRALS OF FIVE-SENSE AND *POKA-YOKE* TECHNOLOGY

| Trigger factor<br>Sense | Weight | Number | Location | Order | Timing | Life of machine part | Number of lines in computer program |
|-------------------------|--------|--------|----------|-------|--------|----------------------|-------------------------------------|
| Sight                   |        |        |          |       |        |                      |                                     |
| Hearing                 |        |        |          |       |        |                      |                                     |
| Smell                   |        |        |          |       |        |                      |                                     |
| Taste                   |        |        |          |       |        |                      |                                     |
| Touch                   |        |        |          |       |        |                      |                                     |

TABLE 3 MATRIX CLARIFYING THE TECHNOLOGICAL FEATURES OF THE INTEGRALS OF FIVE-SENSE AND *KARAKURI* TECHNOLOGY

| Natural Principle<br>Sense | Mechanics | Hydro-mechanics | Magnetism | Electricity | Sound | Optics | Physical properties |
|----------------------------|-----------|-----------------|-----------|-------------|-------|--------|---------------------|
| Sight                      |           |                 |           |             |       |        |                     |
| Hearing                    |           |                 |           |             |       |        |                     |
| Smell                      |           |                 |           |             |       |        |                     |
| Taste                      |           |                 |           |             |       |        |                     |
| Touch                      |           |                 |           |             |       |        |                     |

TABLE 4 MATRIX CLARIFYING THE TECHNOLOGICAL FEATURES OF THE INTEGRALS OF *POKA-YOKE* AND *KARAKURI* TECHNOLOGY

| Natural principle<br>Trigger factor | Mechanics | Hydro-mechanics | Magnetism | Electricity | Sound | Optics | Physical properties |
|-------------------------------------|-----------|-----------------|-----------|-------------|-------|--------|---------------------|
| Weight                              |           |                 |           |             |       |        |                     |
| Number                              |           |                 |           |             |       |        |                     |
| Location                            |           |                 |           |             |       |        |                     |
| Order                               |           |                 |           |             |       |        |                     |
| Timing                              |           |                 |           |             |       |        |                     |
| Life of machine part                |           |                 |           |             |       |        |                     |
| Number of lines in computer program |           |                 |           |             |       |        |                     |

A matrix for integrals of *poka-yoke* technology and

*karakuri* technology is shown in TABLE 4. The components of the vertical axis are six trigger factors: weight, number, location, order, timing, life of a machine part, and number of lines in a computer program. The components of the transverse axis are seven natural principle factors: mechanics, hydromechanics, magnetism, electricity, sound, optics, and physical properties.

## Analysis Procedure

This section discusses the procedure to analyze the integrals of plural lean module technologies and consists of three phases as shown in FIG. 2: The first phase is the collection and investigation of case applications of plural module technologies; the second phase is a merit investigation of the methods used in the collected cases; and the third phase is a discussion of the advantages of integral technologies. All phases are constructed in consideration of the integrals' "needs and seeds." Specifically, the first phase is to clarify the attributes of the technological side of the integrals. The two other phases clarify attributes of the utilization effect. The details of each step are described below.

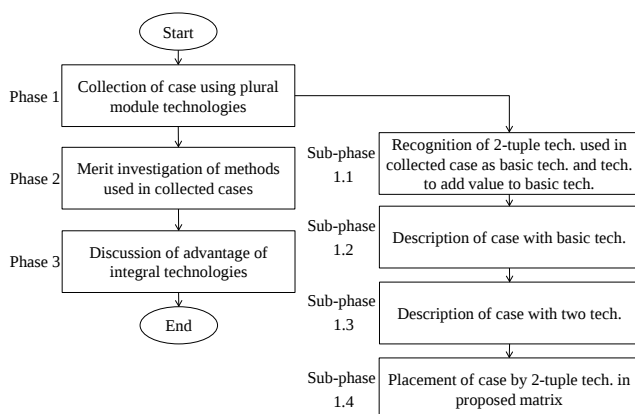


FIG. 2 ANALYSIS PROCEDURE OF INTEGRALS BY 2-TUPLE TECHNOLOGIES

TABLE 5 ANALYZED CASES OF FOCUSED PLURAL TECHNOLOGIES

| Tech. to add value to basic tech. | Basic tech. |           |          |
|-----------------------------------|-------------|-----------|----------|
|                                   | VM          | Poka-yoke | Karakuri |
| VM                                |             | case 1    | case 2   |
| Poka-yoke                         | -           |           | case 3   |
| Karakuri                          | -           | -         |          |

In the first phase, a description of each collected case using plural module technologies is created after case collection through site visits and a literature-based survey. Each description includes several items: the name of the case, its background, the problem resolved through the application to the case, the way

to use plural module technologies in the case, and so forth. In particular, this paper describes cases used in three types of 2-tuple technologies—(1) VM with *poka-yoke*, (2) VM with *karakuri*, and (3) *poka-yoke* with *karakuri*—as shown in TABLE 5.

The case description involves four sub-phases. First, the 2-tuple technologies used in the analyzed case are divided into a basic technology and a technology to add value to the basic technology. Second, a single application of the former technology to the same problem resolved by the objective 2-tuple technologies is described. Third, the analyzed case, which is an application of both technologies, is described. Finally, based on the results of the previous sub-phases, the objective case is put on the proposed matrix for integrals of the 2-tuple technologies.

In the second phase, the synergistic impact of the 2-tuple technologies' application in the analyzed case is investigated. The difference between the two cases is extracted based on seven key performance indicators (KPIs): quality (Q), cost (C), delivery (D), productivity (P), safety/hygiene (S/H), environment (E), and morale (M). The definition of each of the seven KPIs differs, and there are many studies about the definitions of each KPI. For example, morale encompasses 14 aspects (Baehr and Renck 1958): (1) job demand, (2) working conditions, (3) pay, (4) employment benefits, (5) friendliness and co-operation of fellow employees, (6) supervisor-employee interpersonal relations, (7) confidence in management, (8) technical competence of supervision, (9) effectiveness of administration, (10) adequacy of communication, (11) security of job and work relations, (12) status and recognition, (13) identification with the company, and (14) opportunity for growth and advancement.

McFadzean (2005) reported that no useful definition of morale exists, but there are many related studies, including Baehr and Renck's study mentioned above. In this paper, the original definitions of the seven KPIs were discussed and determined with *kaizen* experts in the relevant factories. The following explanations of the seven KPIs are given to support the *kaizen* experts' ratings.

**Quality (Q):** This is critical to improve KPIs related to operation, inspection, and prevention during manufacturing to produce the required product quality.

**Cost (C):** This is related to a reduction of failure cost and maintenance and improvement of job skills.

**Delivery (D):** This is related to the efficient delivery of products/materials from/to the plant.

**Productivity (P):** This is related to the maintenance and improvement of the standard operation time and effective job skills transfer.

**Safety/hygiene (S/H):** This is related to quick information dissemination concerning the cause of a disaster such as a power failure or a fire.

**Environment (E):** This is related to the 5S methodology (*seiri, seiton, seiso, seiketsu, and shitsuke*), conservation of energy in the factory, and safe drainage of accumulated rainwater.

**Morale (M):** This is related to the communication of basic knowledge concerning operations and maintenance and information about the present conditions of the faculties/equipment in the plant.

In the last phase, the general advantages of the integral technologies of each established KPI are summarized based on the merit investigation of the three cases obtained from phases 1 and 2.

### Integrals Case 1: VM with Poka-Yoke

#### Case Description

FIG. 3 is one of the VM cases. Each shelf is labeled to indicate where each different type of good is kept. The function is to decrease the rate of incorrect goods selection from the shelf. The location number of the box is created using by an alphabet on the vertical axis and a number of the transverse axis. However, when operators pick an item from the shelf, they must search for the location of the box where the good is kept.

A digital picking system, one of the cases of VM with *poka-yoke*, as shown in FIG. 4, is developed to resolve the problem mentioned above and makes pinpoint searching for the box location possible. One location number and one lamp are set for each box in the shelf. Information about the number of necessary goods and the location number of the box is registered in the bar code added to an instruction card. When operators select an ordered good from the shelf, they read the bar code and find where the good is kept by looking for the illuminated lamp on the edge of the selected box.

Furthermore, FIG. 5, a digital collecting system in which several digital picking systems are set, is used in the area of collecting and packaging ordered goods

in a warehouse. An empty container is delivered to the area by a conveyor. When the container enters the area and a sensor on the conveyor reads the bar code on the container, lamps light up on the electronic bulletin board to indicate the locations of the shelves where the ordered goods are kept. Operators confirm the locations and collect the necessary goods from the shelves indicated. When case 1 is placed in the analysis matrix based on the above investigation, it is mapped to the sight and location cell, as shown in TABLE 6.

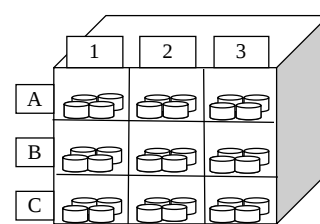


FIG. 3 LOCATION NUMBER INDICATORS FOR EACH BOX (LEFT SIDE)

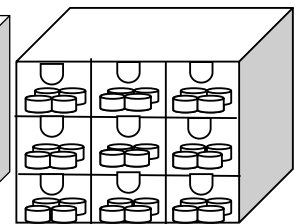


FIG. 4 DIGITAL PICKING SYSTEM (RIGHT SIDE)

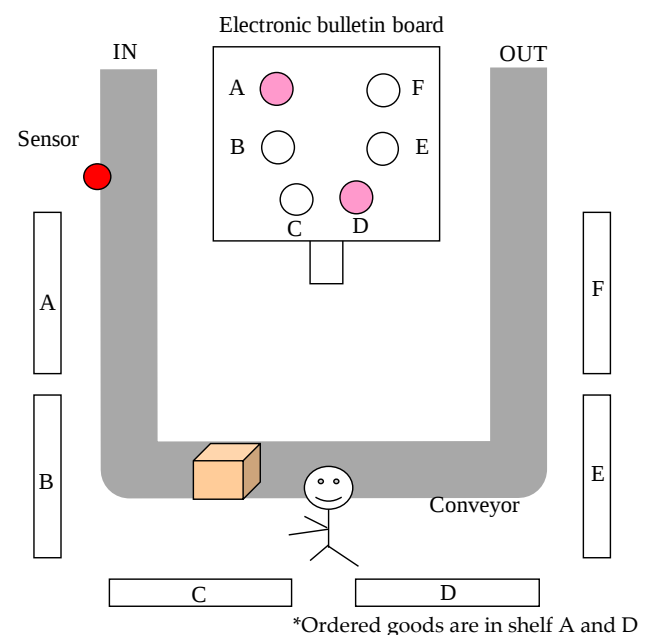


FIG. 5 DIGITAL COLLECTING SYSTEM

TABLE 6 MATRIX TO CLARIFY THE TECHNOLOGICAL FEATURES OF THE INTEGRALS OF FIVE-SENSE AND *POKA-YOKE* TECHNOLOGY (PLACEMENT RESULT FOR CASE 1)

| Trigger factor<br>Sense | Weight | Number | Location | Order | Timing | Life of machine part | Number of lines in computer program |
|-------------------------|--------|--------|----------|-------|--------|----------------------|-------------------------------------|
| Sight                   |        |        | Case 1   |       |        |                      |                                     |
| Hearing                 |        |        |          |       |        |                      |                                     |
| Smell                   |        |        |          |       |        |                      |                                     |
| Taste                   |        |        |          |       |        |                      |                                     |
| Touch                   |        |        |          |       |        |                      |                                     |

### Merit

The results for each KPI in the case using VM with *poka-yoke* as compared to the case with VM only are described below.

**Quality (Q):** The number of customer claims caused by operations failures during the process of collecting and packaging goods could be reduced.

**Cost (C):** The installation cost of the digital collecting system including the digital picking system is high. However, a decrease in compensation for customer claims relevant to picking operations, such as ordered goods shortage and/or unnecessary goods delivery can be realized.

**Delivery (D):** The delivery of ordered goods from the warehouse to each customer will be quick and reliable because of reduced picking operation time.

**Productivity (P):** Incorrect retrieval and confirmation operations will be reduced. Moreover, the number of shelves one operator can manage will be increased.

**Safety/Hygiene (S/H):** Distraction will be decreased, and therefore accidents/injuries during the relevant operation will be decreased.

**Environment (E):** Customers and suppliers will have a clear understanding of the system when the latest sensor technology is introduced on a factory/warehouse tour.

**Morale (M):** New staff and workers with disabilities will be able to be responsible for the relevant operations because of the digital system. Moreover, the case development process provides good training for manufacturing engineers and operators.

### Integrals Case 2: VM with Karakuri

#### Case Description

FIG. 6, one of the VM cases, shows labels for the operating order of a process. The function is to maintain the order. It is used in a distillation column of a chemical plant.

FIG. 7, one of the cases of VM with *karakuri*, shows the cover plate to maintain the operating order. It is developed to strengthen the function of maintaining the order by installing *karakuri* technology. The cover plate is put on the first valve. It hides the second valve until the first valve is used. The second valve is found after operating the first valve when the cover plate moves. When case 2 is placed in the analysis matrix based on the above investigation, it is mapped to the

sight and mechanics cell as shown in TABLE 7.

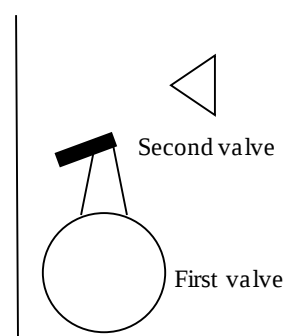


FIG. 6 LABEL TO MAINTAIN OPERATION ORDER FOR APPROPRIATE FLOW IN THE DISTILLATION COLUMN

(LEFT SIDE)

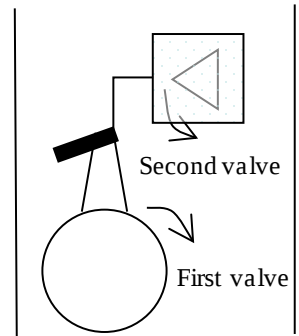


FIG. 7 GAUGE TO MAINTAIN OPERATION ORDER FOR APPROPRIATE FLOW IN THE DISTILLATION COLUMN

(RIGHT SIDE)

TABLE 7 MATRIX TO CLARIFY THE TECHNOLOGICAL FEATURES OF THE INTEGRALS OF FIVE-SENSE AND KARAKURI TECHNOLOGY (PLACEMENT RESULT OF CASE 2)

| Natural principle Sense | Mecha-nics | Hydro - mecha-nics | Magne-tics | Elec-tricity | Sound | Optics | Physical properties |
|-------------------------|------------|--------------------|------------|--------------|-------|--------|---------------------|
| Sight                   | Case 2     |                    |            |              |       |        |                     |
| Hearing                 |            |                    |            |              |       |        |                     |
| Smell                   |            |                    |            |              |       |        |                     |
| Taste                   |            |                    |            |              |       |        |                     |
| Touch                   |            |                    |            |              |       |        |                     |

### Merit

The results for each KPI in the case using VM with *karakuri* as compared to the case with VM only are described below.

**Quality (Q):** Accurate weighted pure water is always supplied to the pot.

**Cost (C):** The case development cost is very low. The recovery cost for pure water leaking from the distillation column will be decreased.

**Delivery (D):** The pure water supply will be realized without leaking pure water from the distillation column.

**Productivity (P):** The total operations of the pure water supply will be performed efficiently because it is unnecessary to consider and confirm the operation order.

**Safety/Hygiene (S/H):** There will be fewer occurrences of unexpected pure water leakage. Thus, the number of injuries caused by leakage will be zero.

**Environment (E):** In the worst case, both pure water and harmful substances could flow outside the plant if

the valves were operated in wrong order. Application of the case contributes to preventing this problem.

**Morale (M):** The case development process using natural principles provides good training for manufacturing engineers and operators.

### Integrals Case 3: Poka-Yoke with Karakuri

#### Case Description

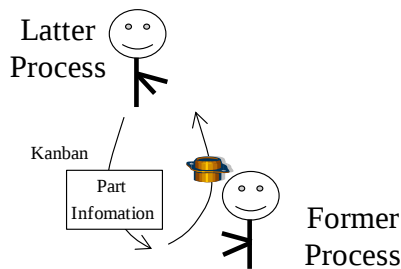


FIG. 8 KANBAN BETWEEN PROXIMATE PROCESSES

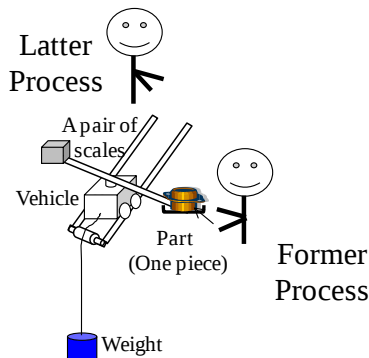


FIG. 9 VEHICLE FOR DELIVERING ONE PART WITH PULLEY (BEFORE MOVEMENT OF VEHICLE TO NEXT PROCESS)

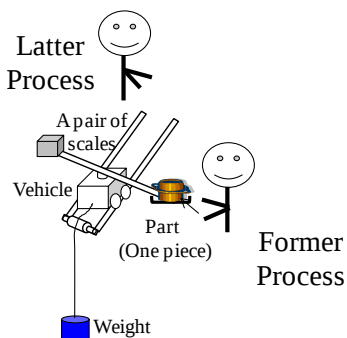


FIG. 10 VEHICLE FOR DELIVERING ONE PART WITH PULLEY (AFTER MOVEMENT OF VEHICLE TO NEXT PROCESS)

*Kanban* used to indicate parts delivery information is an important mechanism supporting just-in-time (JIT) production for the Toyota Production System. FIG. 8, one of the *poka-yoke* cases, utilizes two proximate processes in a production line. A part name and the number of delivered parts are registered in *kanban*. The former process is to begin to manufacture the required parts and supply them to the latter process when *kanban* is delivered from the latter process.

However, it is possible that the former process could manufacture faulty parts. Moreover, a part could fail to be delivered from one process to the other owing to a time lag between part requirement from the latter process and part supply from the former process.

FIG. 9, one case of *poka-yoke* with *karakuri*, shows a vehicle for delivering a part with a pulley to resolve the problem mentioned above. The vehicle is in the former process area when the latter process requires a part. In this situation, the required part is put on a pair of scales, and the vehicle moves the part to the latter process by pulley as shown in FIG. 10. When case 3 is placed on the analysis matrix based on the above investigation, it is mapped to the cell for number and mechanics, as shown in TABLE 8.

TABLE 8 MATRIX TO CLARIFY THE TECHNOLOGICAL FEATURES OF THE INTEGRALS OF POKA-YOKE AND KARAKURI (PLACEMENT RESULT OF CASE 3)

| Natural principle Trigger factor    | Mechanics | Hydro-mechanics | Magnetics | Electricity | Sound | Optics | Physical properties |
|-------------------------------------|-----------|-----------------|-----------|-------------|-------|--------|---------------------|
| Weight                              |           |                 |           |             |       |        |                     |
| Number                              | Case 3    |                 |           |             |       |        |                     |
| Location                            |           |                 |           |             |       |        |                     |
| Order                               |           |                 |           |             |       |        |                     |
| Timing                              |           |                 |           |             |       |        |                     |
| Life of machine part                |           |                 |           |             |       |        |                     |
| Number of lines in computer program |           |                 |           |             |       |        |                     |

#### Merit

The results for each KPI in the case using *poka-yoke* with *karakuri* as compared to the case with *poka-yoke* only are described below:

**Quality (Q):** JIT part delivery is perfectly realized and mistakes in part utilization can be decreased.

**Cost (C):** The development cost of the case is low because the module technology in the case is simple. Moreover, the management cost for controlling *kanban* is unnecessary when the case is applied.

**Delivery (D):** JIT part delivery can be realized. Thus, the waiting time in the relevant process will be decreased.

**Productivity (P):** The number of mistakes in the relevant operation will be reduced and productivity of the operation will be improved.

**Safety/Hygiene (S/H):** Distraction will be decreased



and therefore accidents/injuries during the relevant operation will be decreased.

**Environment (E):** Office implements for maintaining a *kanban* management system, such as paper, calculators, and so forth are unnecessary. Moreover, the case does not require electricity.

**Morale (M):** The case development process using natural principles provides good training for manufacturing engineers and operators.

## Discussion

Based on the analysis of the three cases described in the previous three sections, a general summary of the advantages of integral technologies is provided here. It is found that the development and application of the cases using integral technology contribute to all KPIs.

**Quality (Q):** The reliability of the relevant operation is improved through the application of integral technologies.

**Cost (C):** An economical way to improve the performance of an objective system is provided through the installation of integrals.

**Delivery (D):** A shortened lead time can be realized by decreasing failure and loss in the relevant operations.

**Productivity (P):** Fewer operations are required that do not add value, such as retrieval operations, confirmation operations, and so on.

**Safety/Hygiene (S/H):** Because of the effects described under productivity (P), distraction will be decreased and therefore the accidents/injuries during the relevant operations will be decreased.

**Environment (E):** Because of the effect described under productivity (P), the relevant operations will be more environmentally friendly.

**Morale (M):** The integral development process provides good training for manufacturing engineers and operators. Through an application of integrals, new staff and/or workers with disabilities can be responsible for the relevant operations.

## Concluding Remarks

The following two findings were obtained from the abovementioned trial.

1) General recognition of the merit of integral lean technologies

Clarification of the potential of lean module technologies

is necessary to indicate the merits of lean management for business performance. The finding, which is that using plural lean module technologies creates a synergistic outcome, is regarded as a contribution from the viewpoint of needs. Three future areas of study related to the findings are as follows:

- Quantitative measurement of the merit of the focus integral technologies
- Development of more general instances of *poka-yoke* elemental technology
- Investigation and analysis of integrals using other 2-tuple and more technologies

2) A framework to clarify the technological features of the integrals of plural lean module technologies

The proposed matrices are only for three focused technologies. However, they indicate how to integrate lean module technologies effectively. This contributes to an implementation of lean management. Two future areas of study related to the finding are as follows:

- Collection of cases for each cell of the proposed support matrixes
- Development of procedures to integrate plural module lean technologies

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- Koichi Murata** is a research associate at the Faculty of Science & Engineering, Waseda University, where he received Dr. of Engineering degrees. His research interests are operations & production management, Kaizen strategy & technology, lean management and knowledge management etc.
- Keizo Wakabayashi** is a professor of Nihon University. He received his Ph.D degree in Industrial Engineering from Hokkaido University. His research interests are in area of logistics systems and supply chain management systems. He is a member of The Japan Society of Logistics Systems (JSLS).
- Akihiro Watanabe** is a professor of Nihon University. His research interests are in the area of work design and work measurement management. He is a member of The Japan Society of Logistics Systems (JSLS).
- Hiroshi Katayama** is a professor of operations and production management at the Department of Industrial and Management Systems Engineering, Faculty of Science and Engineering, Waseda University, where he received BS, MS and Dr. of Engineering degrees. His current research interests are manufacturing strategy, lean/agile manufacturing, continuous improvement methodologies, international logistics systems, technology management, etc.